Amorphous Carbon Hard Mask for Multiple Patterning Lithography

TIMOTHY D. HORN

33RD ANNUAL MICROELECTRONIC ENGINEERING CONFERENCE
RIT MICROELECTRONIC ENGINEERING
Outline

I. Background – carbon hard mask advantages

II. Simulation and Experimental Work
   A. PROLITH Simulations of n, k, and thickness
   B. Central composite design

III. Experimental
   A. Equipment setup – Power, Flow, and Pressure
   B. Responses – n, k, and thickness

IV. Conclusions

V. Acknowledgements
Amorphous Carbon Used as an Advanced Patterning Film (APF)

- Has been proven to be effective at eliminating stack reflectivity almost completely.
- Allows for “trimming” of exposed features.
- This has been highly researched for 193nm and 248nm wavelengths.
Double Patterning Lithography

- Enables patterning of features below the lithographic limit.
- Can be performed multiple times to increase line density. (Multiple patterning lithography)

Double patterning lithography realized with positive acting resist. [1]
Double Patterning with Line Width Trimming

- **Line-width trimming**
  - Amorphous carbon, when combined with a capping layer, may be undercut in unexposed regions.
  - This allows for “trimming” of exposed features, enabling a smaller line-width than the photoresist defines.
Justification – Small Feature Sizes at RIT

- Using the multiple patterning concept in conjunction with the carbon line-width trimming step allows for the following:
  - Narrow lines with high density.
  - Line widths approaching 100nm using the i-line (365nm) stepper.
Amorphous Carbon Film Deposition

- Drytek Quad Plasma (Etching?) tool
- Capable of striking a plasma
- Already plumbed with methane (carbon source)
Basic Tool Configuration and Screening Experiment

- Setting up the tool for the experimental runs required checking the following parameters:
  - Power
  - Pressure
  - Flow Rates
  - Time (remains constant at 105 s)

- Comparison of bare silicon and amorphous carbon coated wafers

- Preliminary screening experiment shows ability to deposit carbon using the Drytek quad.

- Measured film with the VASE

![Image of Bare silicon and Carbon hard mask]
Target thicknesses for amorphous carbon and BARC are shown by the red circle demonstrating the area of interest.

This area of interest is chosen based on the lowest reflectivity (shown by the dark blue areas) which also allows for the most process latitude.
The target refractive index for the film is indicated by the large red circle.

Chosen due to the lowest reflectivity, shown by the dark blue areas on the plot.
Experimental Setup

- Central composite design
- Inputs centered around chamber pressure, power, and gas flow rates.
- Responses are n, k, and thickness.
- Set constant time for all samples (105 s).

### Inputs

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<th>CH4 flow (sccm)</th>
<th>Power (W)</th>
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Experimental Results

Using JMP IN, an analytical tool for statistical analysis, the measured responses were optimized to reach the targets.

**Responses**

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Target $n = 1.9$

Target $k = 0.4$

Optimal deposition rate = 64 nm/105 s
Conclusions and Future Work

I. Simulation of an optically optimized carbon hard mask has been done.

II. A designed experiment has verified a simulation model for an optically optimized carbon hard mask.

III. Collection of amorphous carbon etch rates (vertical and horizontal) in an oxygen plasma will be done by a graduate student.

IV. This process module will enable sub-lithographic resolution of approximately 100 nm line width.

Minimum feature size $\approx 100$ nm

Silicon
Acknowledgements

- Dr. Robert Pearson and Dr. Dale Ewbank
  - Guidance through entire design process

- Dr. Santosh Kurinec
  - Sound advice and faculty project advisor

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  - Help with process flow

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  - Assistance and advice
References
